C2 - Adaptive Control Systems

Strategies for controlling complex systems and the battle between central and distributed control.

Background

The history of computer science has shown a cycle of enthusiasm swinging from central processing (main frame with terminals) to distributed processing (Personal Computers) and back again (Cloud Based Platforms) to Mobile Phones (distributed nodes). None are the complete solution and each has its pros and cons, mainly with the moving bottleneck for information exchange.

Lighting systems are critical systems for safety and business performance. It is unacceptable for such a system to "go down", particularly if that breakdown involves the loss of light output.

Due to the complex control algorithms demanded to optimise energy consumption while maintaining both safe and optimal levels of illumination, lighting systems must include sophisticated control systems. Simple PIR activated areas are no longer acceptable. For example a car park that is dark until a PIR sensor is triggered, results in delayed illumination that is both a personal security hazard and a poor energy management strategy.

Initial lighting systems used wired (DALI) control systems and these led immediately to a focus on central computer controls. When DALI was replaced by simple wireless systems, these too simply communicated to a central computer to enable the actual lighting decisions to be made.

Unfortunately, this resulted in lighting systems operating at the mercy of a single component. Any problem with that device, or the communication channel to that device, jeopardised the functionality of the whole system. As a result, in 2016, the Design Lights Consortium issued a recommendation that future lighting systems adopt a wireless distributed control model.[2]

Lessons from Nature - Organic Control Systems

Consider what happens when you touch a hot object. There is a local decision made from your touch sensor (finger) that drives the finger to pull back. There is also a slower signal travelling to your brain, informing it that you have touched a hot object and allowing it to decide whether to take further action. For example focus your eyes upon the object, or decide whether to say "ouch".

The human body uses such systems in many organs. Called ganglions (or ganglia) these nerve cell clusters are located in the autonomic nervous and sensory systems. The ganglia house the input nerve fibres and the output motor nerve fibres for autonomous control. They deliver information about stress or danger and are responsible for the fight-or-flight response. The final ultimate response may be decided by the information from multiple sensor nodes.

In a similar way, an optimal control system will be able to effect immediate responses at a local level, and also be able to combine information obtained from those local reactions to make a more intelligent decision for the benefit of the combined system. Any communications delay or error with

[2] The DLC® is a non-profit organization whose mission is to drive efficient lighting - by defining quality systems for, and providing resources to, the lighting market through open dialogue and collaboration.

the central system will not jeopardise the safety of local occupants nor have any major impact on the performance of the system as a whole.

The Compuspec Adaptive Network - a focus on Distributed Intelligence

The Compuspec Adaptive Network is designed to empower each node; A light fixture, sensor or control node can operate autonomously. The system networks many thousands of distributed nodes, each capable of making decisions to optimise local illumination based upon the local and neighbouring environment. Every node is essentially the same, cloned throughout the network. With no dependence on a central control system, the system not only reacts in real time, but it becomes incredibly rugged and reliable.

One of the unique advantages of this system is that nodes can "swarm" to follow dynamic activity. Dynamically coupled groups of light fixtures can "follow the action" based upon forklift movement or human traffic. Groups are dynamically formed based upon their proximity to the activity and can provide a continual pool of light to follow the task, while passive areas can receive less illumination. This optimised energy use can achieve 90% savings in many applications.

Even though fully autonomous, the nodes still follow sets of rules that limit their freedom. For example, they will have minimum and maximum allowable illumination levels that they must work within and they will maintain a comfortable rate of change of illumination levels. However, within these restrictions they are at liberty to function so as to best optimise the current system priority. The actual system priority may change, for example there may be a need to keep peak electricity demand constrained, or there may be a desire to limit energy use depending upon solar gain available from a solar array.

Addition of Sensor Nodes

The Compuspec Adaptive Network solution allows the addition of static or dynamic sensor (or control) nodes that can report on, or control, local environmental conditions. These might range from air quality or temperature sensors, to fork lift battery condition monitors, or even asset tags that can be tracked for location monitoring.

By utilising the lighting control network, information can be gathered throughout a facility *without needing to access occupants' secure WiFi networks*. Because the system forms a dynamic mesh between nodes, and with up to 1km between nodes, information can be passed from floor to floor in a high rise building, or between workshops and buildings on large industrial sites. This information is securely stored locally within each node and relayed to a central system for monitoring and control as required.

Organic Networks - Adaption and Evolution

Due to its dynamic operation, the Compuspec Adaptive Network can add and delete nodes in real time allowing "self healing"; where the addition or absence of a node is automatically repaired or absorbed without impacting the overall system health.

Over-The-Air firmware upgrades allowing new algorithms to be replicated throughout the dynamic network. The system can therefore be upgraded to benefit from newer algorithms.

Enhanced Lighting using Radio Proximity Beacons

To further enhance energy savings, the Compuspec lighting network can interact with mobile Proximity Beacons. These small transponders are fitted to moving equipment and transmit "Light Level Requests" to request from the lighting network the level of light that they need to perform their task.

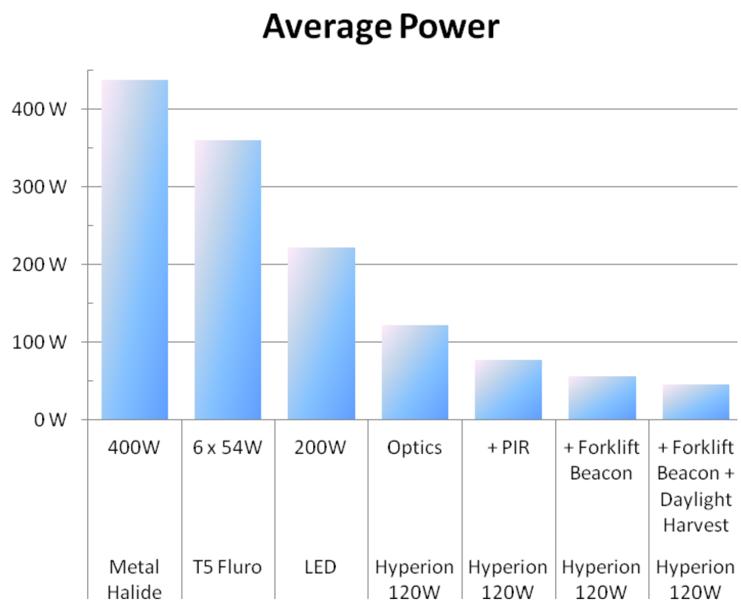
Typically the lighting system is set so that minimal light levels are maintained throughout the site (meaning idle areas of the site are still illuminated for safety and comfort, but are drawing minimal power). When a machine is turned on, its Beacon starts emitting a Light Level Request every second. The transmission range of this beacon is about 1km. This signal identifies what level and how far around the equipment illumination is required

Any lights within the beacons range will evaluate the lighting request and decide whether or not they need to change their illumination level to suit the request. Based upon the range and level requested, lights in the area will ramp up (or down) to provide the required illumination.

As the machine moves around the site, new lights will decide they need to increase illumination around the task, while other lights will decide they are no longer required and can dim down. Thus a programmable pool of light follows the activity around the site. We often describe this as a "Swarm" of lights that follow the activity, or the lights "Hunting in Packs".

Because the lights are autonomous, there is no need for a central control system and there is no limit on the number of moving objects (beacons) employed. This makes it incredibly rugged, with pools of light able to overlap and multiple objects moving at random.

The largest sites using this system currently have about 200 forklifts simultaneously operational, as well as some manual staff (using Personal Beacons).



Motion sensors can deliver some energy savings, but are restricted by mounting height and angles of view. They cannot pre-empt motion. In this system, areas in front of the motion are illuminated in advance of the activity (including around corners), and the area around the activity is fully illuminated, so the operator is not even aware that the system is "turning the lights off" when they leave the area.

The system is also failsafe and can be retrofitted at a later date. This is because the lights operating independently of the Proximity Beacons. If the beacons are turned off, the system reverts back to its basic operating mode (which might include daylight harvesting and PIR proximity functions).